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In this paper the elements of a generic end-to-end information framework are proposed in terms of a network centric warfare concept. The specific example described is precision engagement (*Joint Vision 2010)* involving the detection, identification, and attack of mobile land targets. System element relationships are described using a simplified decision making process framework: sense – interpret – decide – act. The proposed precision engagement framework is explored in the context of total ship engineering. Challenges are identified in achieving the vision of a ship, engineered to be part of a total network centric force; naval, joint or coalition.

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A Network-Centric Framework for Engineering Future Naval Platforms

ABSTRACT

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INTRODUCTION

Joint Vision 2010 and *Concept for Future Joint Operations* provides a conceptual framework for how U.S. military forces will organize and operate in the future. These documents assert that successful execution of operational warfare tasks requires a joint approach that links surveillance and reconnaissance, intelligence assessment, command and control, mission preparation, and mission execution at all levels. Further, it is stated that concepts for future warfighting capabilities all require heavy reliance on advances in technology, and particularly information technology. The Navy's vision, as set forth in *Forward ...From the Sea*, describes a concept of a powerful, fast striking, geographically dispersed force that exploits information superiority to rapidly overwhelm its adversaries. This approach is network-centric warfare. It is a fundamental shift from platforms to networks as the nucleus of combat power. The Navy, however, procures platforms and not network-centric capabilities. The problem therefore is how to engineer the future force and the platforms that comprise the force in order to achieve the Navy's and DOD vision.

Traditional ship design considers the trade space composed of speed, endurance, payload, survivability, seakeeping, and sustainability as it satisfies the mission capability needs of the warfighter. Future ship design in the context of network centric warfare requires a more expansive perspective. Figure 1 is an example of what that larger view might include – mission capabilities, network centric operations, and platform trade space. Note that the arrows are two-way, depicting the inter-relationships that exist between the areas.

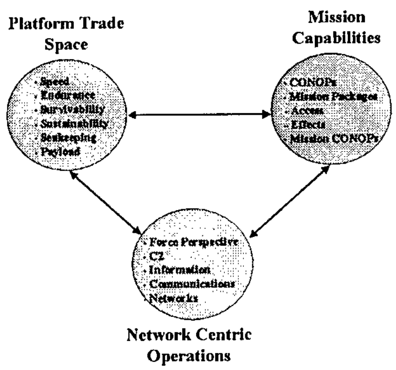

FIGURE 1. Mission – Information – Platform Trade Space

Under the mission capabilities are the overarching concepts of operation for the class of ship, the mission capabilities required to achieve access or cause effects, and the concepts for how the missions will be carried out.

Network centric operations encompass those elements that fight the total force and include the information upon which commanders make decisions, the tools to assist warfighters in making decisions, and the networks to move the information around the system.

A framework is needed to in which to provide the network centric warfare insight into the total force and individual platform engineering process. This paper explores the building blocks for such a framework drawing on the conceptual guidance of *Joint Vision 2010* and Navy writings on Network Centric Warfare.

Joint Vision 2010 proposes four new operational concepts – precision engagement; dominant maneuver; full-dimensional protection; and focused logistics. Precision engagement was chosen for this paper, although any of the concepts could have been used. *Joint Vision 2010* defines precision engagement as:

> "A system of systems that enables our forces to locate the objective or target, provide responsive command and control, generate the desired effect, assess our level of success, and retain the flexibility to reengage with precision when required."

All the operational concepts in *Joint Vision 2010* rely on networked systems for the movement of information and to control forces. Vadm Cebrowski, and others, has proposed a network centric logical model to describe network centric warfare. The model (figure 2) consists of sensor and engagement grids (distributed sensors and shooters) with distributed command and control of both grids. A ship platform carries portions of both of these grids – sensors, weapons, processing, and command and control. Overlaying these two grids is an information grid that ties the sensor and engagement grids together and moves data and information to support the actions and decision-makers in the system.

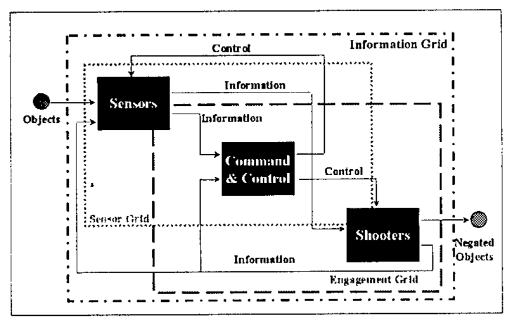

FIGURE 2. Logical Model for Network-Centric Warfare

The logical model requires expansion of the command and control portions in order to better understand the information needs of the decision-makers in the system and therefore the engineering implications to the force and platforms. Dr. Joel Lawson discusses several such models that are adapted for this paper. Our simple model has four components - Sense, Interpret, Decide, and React (figure 3).
In assessing a precision engagement capability, the knowledge that is required to accomplish the mission was explored - mission planning, mission execution, and mission assessment. The precision engagement framework developed identifies the functions that need to be accomplished throughout the system, the relationship between the functions, the flow of

information between elements of the system, and

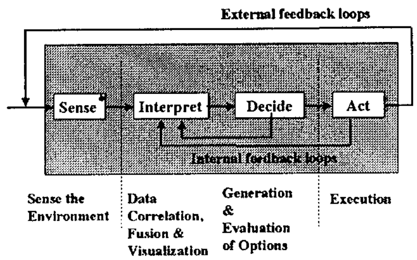

FIGURE 3. Decision making Process Model

the control of the sensing and action functions. Network-centric warfare requires a shift in focus from fighting an individual platform to fighting as a force (while not losing the ability to fight the platforms). The information revolution – with its computers and communications capabilities – allows the ability to share information across the entire force to facilitate rapid decision making. While not all the operational aspects of network-centric warfare are fully understood, it is expected that this new style of warfare will allow rapid decision-making and the ability to mass effects and not forces across a broad area of interest.

ELEMENTS OF A NOTIONAL PRECISION ENGAGEMENT SYSTEM

For the purposes of this paper, a notional concept will be described that assembles a number of shipboard or other multi-mission platform components tied together in an end-to-end fashion. This will then be applied to a DD 21-like land attack scenario of finding and attacking moving targets over a large area. The scenario boundaries are those assigned to the Joint Task Force Commander by the regional commander and include the Joint operations area, the mission assigned, and the resources assigned directly to the Joint Task Force Commander. Additional resources from outside the system may be requested for either direct control or on a case-by-case basis. Additionally higher authority can influence events through changes in policy or guidance.

The roles of the fundamental elements of the decision making process model for this scenario are described below:

Sense. The sensor grid provides the data necessary to build a picture of the battlespace of interest. Many sensor types and numbers are needed to provide a capability that will enable the warfighter to cover a wide area of interest and to search for, detect, and identify potential targets of interest. The target type, environmental conditions, and operational posture will determine which sensor types are most likely to provide the information necessary for a decision maker to act. For the scenario of searching a wide area for moving targets with shipboard and organic assets, sensor types could vary depending on the target signature being exploited – visual, heat, acoustics/seismic, electronic emissions, or radar.

For this scenario, the sensor grid is composed of shipboard, platform and other multi-mission Theater Assets controlled by the operational commander and National Assets controlled by other entities outside the Joint Task Force. Some examples of the type of sensors that could be in the grid are synthetic aperture radar, real aperture radar, electro-optical, visual, acoustic, and passive receivers of electronic emissions. Potential theater assets might include unmanned air vehicles with synthetic aperture radar or electro-optical sensors, Joint Surveillance Target Attack Radar System with moving target indicator synthetic aperture radar, manned aircraft with visual and electro-optical sensors, special operations forces on the ground with visual and electro-optical sensors, unattended ground sensors with acoustic sensors, and ship-based radar. Potential assets controlled at a higher level might include spaced-based assets with radar, optical, electro-optical, and signals intelligence sensors, high altitude manned and unmanned surveillance aircraft, and human intelligence sources.

The raw sensor data can be processed onboard to generate targeting information or can be sent on-shore for remote processing and fusing with other sensor data. Examples of onboard processing include manned aircraft carried moving target indicator radar, shipboard combat system processed radar, manned aircraft machine and human processed sensor data, and special operations forces employed systems. Other sensors will transmit data by communications links to ground stations or ship command centers for processing and interpretation. In some very special cases, there are direct sensor-to-weapon connections for weapon direction and control.

Interpret. Interpretation involves correlating and fusing data and building a "picture" of the battlespace from sensed and archived data and how that picture is changing relative to own-ships' force location and mission assigned. This process will be distributed throughout the force. Correlation and fusion involves the complex multi-level process of evaluating data and information and determining what other data is required as well as getting the right data to the right user at the right time without overloading the communications network. Interpretation is done throughout the force, from the sensor operator to the operational commander. Taken further, during the engagement phase, pilots interpret the situation and make necessary adjustments and, in some cases, weapons have the capability to make "end game" adjustments. The processes required to support the various decision-makers however is very different. The sensor operator is most interested in the battlespace that is in the immediate area of the sensor. The operational commander is interested in the entire battlespace that he is responsible for – targets of interest, threats to own forces, environmental conditions, etc. The network contains other decision-makers: multi-sensor fusion operators, ship commanders who are responsible for the safety of their ship and for positioning the ship's payloads, and warfare commanders who are responsible for the planning and execution of a segment of an operation.

Decide. Commanders and their subordinates make decisions throughout the force. Commanders will usually delegate certain decisions to their subordinates based on the commander's intent and the rules of engagement under which the forces are operating. Decisions include actions to move, revisit, change asset allocations, request additional assets, attack targets, etc. The decision process relies on the data and information from resident databases and the output of the "Interpret" function to generate and evaluate potential action options. In certain cases, decisions must be made very rapidly in response to external stimuli. The generation and evaluation of potential responses is replaced by a response based on training to react in a specified manner to certain recognized patterns rather than rapid evaluation of several potential actions.

Decision-makers will act on processed data generated by organic sensors, as well as, data and information from external sources, such as, national sensor information, environmental information collected and evaluated external to the system, and intelligence data produced at the Theater Commander or National levels. This data and information will be supplemented with static and dynamic information data bases and decision support and mission planning tools.

Act. A decision leads to action. Actions range from the reallocation of sensors to the deployment of weapons. For the sensor grid, actions consist of placing sensors in appropriate locations to build and maintain a picture of the battlespace and of reporting status and results to higher authority. If time allows and insufficient information is available on which to make a decision, then sensors controlled by the commander may be reassigned to further develop the battlespace picture. Additionally, the commander may request more sensor assets from higher authority to provide further resources to build knowledge of the battlespace. Other action would be providing information to higher authority concerning enemy operations or intended actions.

For the engagement grid, actions consist of responding to the knowledge of the location of enemy targets. These responses include providing direction to shipboard or other weapons delivery platforms and orders for specific weapons launch. The actions must include the orchestration of the delivery platforms and weapons. In essence ensuring the proper time and spatial separation of all objects, manned and unmanned, moving through the battlespace. Note in some instances that there will be direct feedback of both information and control from the engagement to the sensor grid to reflect specific weapon considerations. Figures 4 and 5 depict a representation of the sensor and engagement grids.

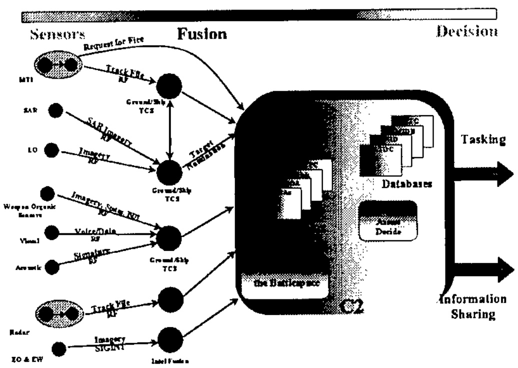

FIGURE 4. Precision Engagement Sensor Grid

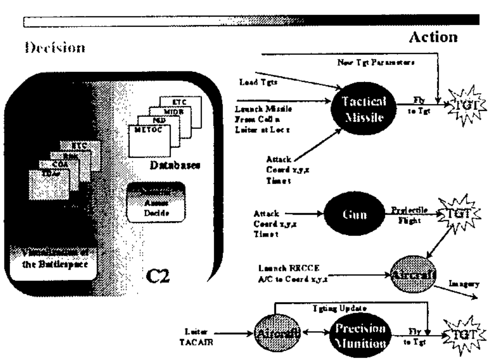

FIGURE 5. Engagement Grid

The information and control flow is key to describing the functional architecture. These figures are drawn with a hub and spoke relationship, but there is also an information grid to inter-connect all the nodes and provide the foundation for data and information sharing. The framework also does not graphically depict its characteristics with multiple numbers of sensors, fusion nodes, decision-makers and decision-making locations, and weapon delivery options.

While Figures 4 and 5 represent a single view of the overall network-centric framework, the architecture needs to generate the knowledge to allow the warfighters to address the situations they are faced with. Specifically for the moving/mobile target problem, the force capability must generate the knowledge to establish the mission, execute the mission, and finally to assess overall mission effectiveness. In all cases, the information generated needs to answer the typical newspaper reporter questions – what is the context, why or why shouldn't action be taken, who is involved, what knowledge is important, where are key items located, when do things need to occur, and how are tasks to be executed.

For the framework described, the command and control node needs to be looked at in more detail. The command and control functions performed in the precision engagement system can be viewed as allocating or reallocating the sensors in the system, searching for the objects of interest (targets), planning the missions, executing the missions, and conducting a battle damage assessment.

The command and control decision process for sensor allocation and reallocation receives inputs from outside the boundaries of the Joint Task Force system. From higher authority the overall mission, the resources to do the mission, the commander's intent and rules of engagement are received and provide the basis for planning the operation. Meteorological and oceanographic data are received from shore support activities to update previous databases and in-situ collected data. Intelligence updates are received from intelligence sources to augment and update previously collected and archived databases describing the battlespace of interest. This database should contain known target locations, target technical characteristics (including signatures and vulnerabilities), infrastructure locations and characteristics, and potential threats to sensors and sensor platforms. These databases provide the initial picture of the battlespace. Search planning tactical decision aids need to generate recommendations for optimum sensor allocation based on resources available. The decision aids also need to support the deconfliction of sensors and platforms from sensor interference perspectives and safety considerations. Decision aids need to provide course of action and risk assessments and assist in prioritizing tasking. Comparison of the output of the decision aids with the initial picture of the battlespace assists in determining the required battlespace knowledge to conduct a mission. The output of this process will be tasking for the sensors controlled by the operational commander and reports of status and plans and requests for additional resources to higher authority.

Command and control for target search is an extension of the sensor allocation process. Tasked sensors and external intelligence update the initial picture of the battlespace and search execution monitoring identifies target locations, areas searched (with time stamps), and areas with potential targets. Search re-planning continues for sensor direction and reallocation, deconfliction of sensors and platforms, and prioritizing of sensor tasking. Outputs include sensor tasking (scheduling and guidelines), target nominations and coordinates to the engagement grid, and a battlespace picture and request for additional resources to higher authority.

The command and control decision process for mission planning receives target nominations and coordinates from the search function and intelligence and environmental updates from external sources. Mission planning uses sensor inputs from the search function combined with existing data bases of target technical characteristics, information concerning the infrastructure, and threats to delivery systems to build an initial picture of the battlespace. Mission planning decision aids explore options for employment of the resources available – delivery system allocations, weapon allocations, and delivery route allocations and deconfliction. The output is mission execution tasking and status reports and requests to higher authority.

While mission planning provides the high level details and decisions about a mission, e.g., allocating delivery platforms and weapons across several missions, mission execution provides the detailed decisions and information necessary to act against a specific target set. Inputs to the process are the mission execution tasking and reconnaissance targeting data from the sensor grid. Again external sources provide intelligence updates and environmental data. Tools help to visualize the targets and potential target areas and potential threats to delivery systems. Using the available resources, detailed engagement planning provides for weapon target pairing, deconfliction of platforms and weapons for the specific mission, and tasking prioritization. The outputs of the process are platform and weapon tasking, battle damage assessment instructions, and information to higher authority concerning the execution plan and status. Note that the functional description applies equally when the engaging platform also happens to be a sensing platform as well.

The command and control decision process for battle damage assessment execution receives information from sensors and assessment instructions from mission execution. Updated information is potentially available from external intelligence and environmental collection and forecasting sources. The process interprets sensor data - areas covered and target damage - to determine target status. Where additional sensor data is needed, search planning tools assist in directing and reallocating sensors. Where re-attacks are needed, decision aids assist in weapon and platform selection. The process output is sensor re-tasking, target re-engagement information for feedback into mission planning, and a status report to higher authority.

WHERE WE ARE TODAY

While today's shipboard and other multi-mission platforms, sensors, weapons, and decision support tools were not designed for network - centric precision engagement, they will form the basis of any future networked knowledge based capability. Thus, it is worthwhile to review how these legacy capabilities might work in a network centric approach against our moving target example.

Wide area surveillance is provided by satellite and manned and unmanned aircraft. Aircraft, ships, and people provide more detailed surveillance and location information. Figure 4 provided generic sensors that are associated with existing systems. The synthetic aperture radar with moving target indicator capability is currently flying on the Joint Surveillance Target Attack Radar System and Global Hawk aircraft. This provides good location information against moving targets and partial identification. Conversely if the target of interest is not moving, no information is available. On-board the Joint Target Attack Radar System aircraft is an aircrew that can provide both direct request for fires or a composite picture to a ground station for further data fusion and decision making. This system is limited in coverage in pre-hostility situations due to overflight considerations and during hostilities due to vulnerability to anti-aircraft defenses. High altitude manned aircraft and the Predator unmanned air vehicles are platforms for synthetic aperture radar and electro-optical sensors. Raw sensor data is passed by radio frequency links to ground stations for processing and interpretation. These aircraft-carried sensors are limited in coverage during pre-hostilities due to overflight considerations and in hostilities the electro-optical sensors are limited by weather and for some sensor types by light conditions. Satellite carried synthetic aperture radar, electro-optical and signal intelligence sensors provide unimpeded surveillance during pre-hostilities and hostilities. For a single satellite the revisit time does not provide the type of coverage needed for the moving target problem. While multiple satellites could provide the coverage, the cost is very high. Endurance unmanned air vehicles, such as the planned Global Hawk, should provide a viable alternative. Sensor data from satellites is sent to ground stations and may not be directly available to the area commander. Local area surveillance and reconnaissance sensors on ships, aircraft, and with ground forces provide both information on focused geographic areas and targeting. Radar, electro-optical, and visual sensors on manned aircraft provide search and targeting information. Special operations forces with visual and electro-optical sensors provide search and targeting information to the network. A new class of sensors, termed unattended ground sensors, use acoustic signatures of moving vehicles to generate detection and targeting information.

Distributed command and control is essential to the network centric concept. Command and control is distributed, but the major node in today's strike system is the Joint Forces Air Component Commander. The decision making process uses decision aids for search, mission, and engagement planning. Sensor information, combined with intelligence and environmental databases, provides the knowledge of the battlespace on which decisions are made. Current databases were designed for specific purposes and may or may not be suitable for fusion processes. The time to turn sensed targets into direction to the weapon severely impacts the ability today to address moving targets. All of these are challenged to meet projected engagement timelines.

We are in the process of introducing precision guided munitions that with accurate targeting information can attack moving targets. Aircraft launched Joint Direct Attack Munitions and Joint Standoff Weapons provide fire and forget GPS guided capability, but require loitering aircraft for delivery. Standoff Land Attack Missiles – Expanded Response also provide fire and forget capability, and allow attack at long ranges. The ship launched Land Attack Standard Missile provides a fire and forget attack capability. The ship and submarine launched tactical Tomahawk will provide a long range capability with loiter and re-target capability. Ship gun systems are in the process of receiving increased range projectiles with guidance that will provide another means of responding to time critical targets.

CHALLENGES FOR NETWORK CENTRIC PRECISION ENGAGEMENT

As this specific example illustrates, many challenges exist in providing an assured attack capability against the full range of stationary, moving, partially obscured and fully obscured targets. Network centric precision engagement offers promise in providing this capability.

However, attention needs to be given to the following:

- Interoperability: Tomorrow's precision engagement capability will be comprised of many systems that exist today and yet were designed as stove-piped systems. This is manifested in interoperability problems between U.S. Navy systems, is more problematic in Joint operations, and is even worse in Coalition operations. Interoperability problems include the ability to communicate among all elements of the force, incompatible data bases, errors in navigation systems, and different planning tools and decision aids. The challenges are in moving towards a fully knowledge-centric capability while incorporating legacy systems and defining standards for new system development.
- Disadvantaged users: One approach to solving many of the data and information needs of a net-based capability is to send raw sensor data to all the users and to let individual decision makers operate on the data to make a decision. However, many of the participants on the network are associated with platforms (or ashore) that have insufficient real estate for the antennas necessary to receive the data. The challenge is to do the information engineering necessary to determine the actual information needs of the decision-makers throughout the network and only transmit what information is needed by each decision-maker, and when.
- Sensor coverage: The ability to provide the continuous wide-area surveillance coverage necessary to target mobile missile launchers remains a real challenge. Those sensors with the necessary continuous coverage and resolution are now payloads of aircraft that are vulnerable to anti-aircraft defenses. The ability to detect these targets in partially or fully obscured locations is required to have a credible capability to counter mobile missile launchers. Further, sensor improvements are required to combat adverse weather and low light conditions.
- Command and Control: Time is critical against moving targets. The ability to recognize the target and respond with a weapon within the time window available is the challenge of the command and control process. This includes those processes delegated to machines and subordinates as well as those decisions made by higher level command.
- Data - Information – Knowledge: Decision-makers need the right information at the right time in order to make the right decisions. The challenge is to understand the data and information needs for creating information and subsequently knowledge. While networks offer the potential of data flow from one end of the force to the other, the content of the data and information that flows throughout the force elements is critical to generating the knowledge for rapid and accurate decision making.
- Fusion Nodes and Information Flow: Fusion nodes in today's system generally are associated with the sensor and are not integrated into an overall capability. In a network centric system, these fusion nodes are a potential bottleneck. One workaround being pursued is to downlink raw data from many airborne and overhead sensors directly to a fusion node on a command ship or other large combatant. This approach has the potential for drastically increasing the communications bandwidth requirements and the workload of the afloat staffs. Antenna considerations preclude smaller ships from receiving the data. An additional challenge today is recognizing targets in the environment in which they operate. Automatic target recognition processes are making progress in detecting targets other than those in the open. Detecting and classifying partially or fully obscured moving targets still remains a problem, but with encouraging progress in the measurement and signature intelligence arena.

THE GREATER CHALLENGE

As illustrated above for the precision engagement scenario for land mobile targets (a relatively limited scenario) the challenges associated with network-centric based systems for shipboard applications are diverse and complex. Recent observations by the authors at the GLOBAL 99 War Game and perusal of the "lessons learned in Kosovo" briefings from the Chief of Naval Operations staff have, while reinforcing the challenges in the previous section, highlighted larger aspects of the problem. While Network Centric Operations are a necessity for Effects Based Operations, the network solutions are not sufficient. The Network must allow the free flow and access of information and provide this in a timely and transparent manner to all levels of command and execution, but the ability to use this information, convert it to knowledge, understanding and ultimately to decision and action is a much larger issue. At the Naval War College there is discussion of this higher level "Knowledge Centric" view and it is important. It requires looking at the decision process itself including group behavior and cognition and the organizational structure of operations in the new environment. It also requires a look at the technology of tools for decision support, distributed collaboration and human computer interaction. On the human side it requires the development of concepts, doctrine, tactics, techniques and procedure to work in this new environment. Above all, it requires training and practice, top to bottom, with our forces and the forces of our Allies and many coalition partners.

OPPORTUNITIES

The engineering decisions made by platform designers greatly impact the capability of a networked force. In the paradigm illustrated in Figure (1), mission capability and platform trade space must be dependent upon each other; and in the context of the "greater challenge" must be better defined. The linkages between platform trade space, mission capabilities and network centric operations begs for a process – the opportunity. In the past engineering approaches were very tightly linear in nature and driven by decisions that were based on a limited perspective on what future mission requirements would emerge with changing world conditions. In the future engineering processes must be able to cope with changing mission requirements and technological opportunities.

This is an opportunity for the Navy acquisition community and operational commands to participate together to address the mandates of *Joint Vision 2010.* A collaborative process – a joint venture in commercial terms, must replace the days of stovepipe programmatics. The technical issues and complexity highlighted in this paper that must be solved to do Precision Engagement with network centric operations illustrates this point. Developers of individual systems need to interact with the platform trade space. Navy program sponsors of information systems must consider platform trade space issues and collaborate with the platform program sponsors. Systems developers and payload providers must include in their list of trade space issues and systems requirements platform trade space. Systems requirements must include not only traditional performance statements but include items that affect the overall capability of the platform as a network node over the 40 year plus life of the platform like staffing, volume, weight, operating needs, survivability, life-cycle cost, training, modernization, scalability and flexibility. The trade space must include considerations for an evolving platform, especially those components that interface with the mission systems; i.e., topside configurations, navigation, and shipboard local area networks and payload configuration – and avoid decisions based on a fixed set of missions and concepts of operation.

Figures 6 offers a framework for this opportunity, a framework for engineering future naval platforms that is consistent with the current paradigm (figure 1) but takes an evolutionary step toward defining the processes that become the links in the paradigm. It is of course not the final solution, but a point of departure. Functional layers must be added and good systems engineering must be followed during execution. In this framework the initiation of design is contingent upon having defined concepts of operation and architectures for information systems and combat systems functions for the platform and the force within which it will operate. And it can be implemented by government, industry and government-industry teams.

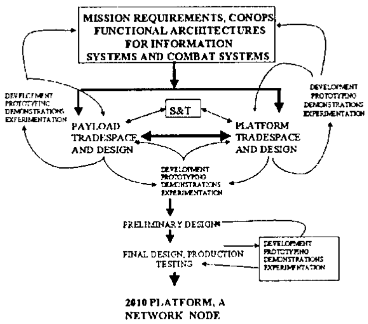

FIGURE 6. Engineering Frame work for Mission Centered Design

The proposed framework has three fundamental levels, each encompassing multiple activities. The top most level and entry point is the *context* level. The *context* level goes well beyond the intent of a "Mission Needs Statement" now needed for Milestone 0. It requires that mission requirements and concepts of operation be defined and that functional architectures exist for combat and information systems in a network organized force. This context is essential for taking the step into the *innovation* level.

In the *innovation* level there must be a "payload "manager" with influence equal to the "platform manager". At this level transition of Science and Technology (government and industry) products via "producers" should facilitate innovation. The opportunity for innovation to influence concepts of operation and architectures becomes part of trade space decisions. This level also includes an assessment of alternatives, concept development and preliminary design with robust and relevant trade space considerations. It is during this layer that systems development, prototyping, demonstrations and experimentation begins to facilitate tradespace decisions. The *innovation* level thus can involve developmental iterations. A preliminary design is the exit point for this level.

The *production and test level* includes activities of final design and payload installations. It utilizes the principles of evolutionary acquisition for information systems and information elements of combat systems. It leverages commercial off-the-shelf components, land-based testing of payloads prior to installation, and other production "best practices." The payload manager and the platform manager must continue to work as equals during this level.

CONCLUSIONS

This is a very large and seemingly overwhelming task. But we have no choice, the information age is well underway, information technologies are becoming omnipresent. The "Genie" will not go back in the bottle and Navy must learn to play and win in this New World. We cannot succeed with outmoded structures and processes. This is why the concept of engineering a "total ship" is important and necessary. Engineering a ship as a complete entity is a new paradigm but with the rate of change currently extant it to is insufficient. In the new environment Navy ships and air platforms must be engineered as elements of a "total force."

REFERENCES

Cebrowski, A. K. and J. J. Garstka, "Network-Centric Warfare, Its Origin and Future," *Naval Institute Proceedings*, January 1998.

Joint Vision 2010, Chairman of the Joint Chiefs of Staff, Washington, DC, July 1996.

Lawson, J. S., "Command Control as a Process," *IEEE Control Systems Magazine,* Volume 1 Number 1, March 1981.

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